

Temporal and Spatial Distribution of Paralytic Shellfish Poisoning (PSP) in Puget Sound Embayments

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Introduction

The Washington State Department of Health is mandated to protect the health of consumers from shellfish contaminated with toxins, including biotoxins, such as paralytic shellfish poisoning (PSP) toxin. To meet the mandate, DOH monitors shellfish from hundreds of sites throughout the marine waters of Western Washington.

Paralytic shellfish poisoning occurs when people consume shellfish containing excessive levels of PSP toxin. Paralytic shellfish poisoning has also been noted in populations of birds and marine mammals. Excessive levels of PSP toxin are produced by the dinoflagellate *Alexandrium catenella* during blooms that usually occur from spring through late autumn.

PSP toxin is one of a family of neurotoxins called saxitoxin. Saxitoxin disrupts nerve transmission. Symptoms can progress from numbness and tingling of lips, loss of muscular coordination, to respiratory arrest and death. Symptoms develop after 1–2 hours of eating contaminated shellfish. There is no known antidote. Death results in about 15% of cases worldwide (Nishitani et al., 1994). The U.S. Food and Drug Administration has set a standard for PSP at no more than 80 micrograms of PSP toxin in 100 grams of shellfish tissue.

PSP has a long history in northwest waters. In June 1793, four crewmen with Captain Vancouver's expedition became sick and one died shortly after eating shellfish along the coast (Strickland, 1983). Several PSP-related deaths occurred in 1942, which prompted the annual closure of the Strait of Juan de Fuca and the coast. By the 1970s, closures were occurring in the San Juans and Bellingham. In September 1978, heavy rains followed by warm "Indian Summer" weather produced a number of PSP illnesses from Saratoga Passage to as far south as Vashon Island (Strickland, 1983). In 1988, excessive PSP levels were detected in shellfish from Carr and Case inlets in south Puget Sound. In 1992, PSP went above the detection limit (38 micrograms per 100 grams shellfish tissue) in Hood Canal shellfish as far south as Seabeck.

In the late 1980s, the Puget Sound Water Quality Authority established the Puget Sound Ambient Monitoring Program (PSAMP). As a PSAMP agency, DOH designated a number of PSP sampling sites throughout Puget Sound and the Strait of Juan de Fuca to address PSAMP goals. This technical report addresses two questions based on PSAMP goals: 1) how levels of PSP toxin in shellfish change from place to place and over time; and 2) whether changes are related to human activities. The following analysis is an attempt to address these questions.

Methods

PSP sites are usually sampled twice a month by citizens, shellfish growers, or staff of counties, tribes, or DOH. The sampling frequency is increased in the event PSP in shellfish rises to unsafe levels. Blue mussels (*Mytilus edulis*) or several other *Mytilis* species are sampled "wild" from floats, pilings and rocks, or are taken from wire mesh cages (40 cm x 40 cm x 20 cm; 2.5 cm mesh size). These cages are suspended about one meter deep below floating docks. Seventy to 100 mid-sized mussels are taken to provide 100 grams of tissue for analysis. The mussels are put into one-gallon ziplock bags, packed into ice-bearing boxes, and shipped to the W.R. Geidt Public Health Laboratory in Seattle. The samples are analyzed with the mouse bioassay (APHA 1984).

PSP toxin in shellfish (where it occurs) is variable from year to year and within the same year. This variability is evident in Figure 1. Figure 2 shows an expanded view of 1992 (enclosed in the box in Figure 1).

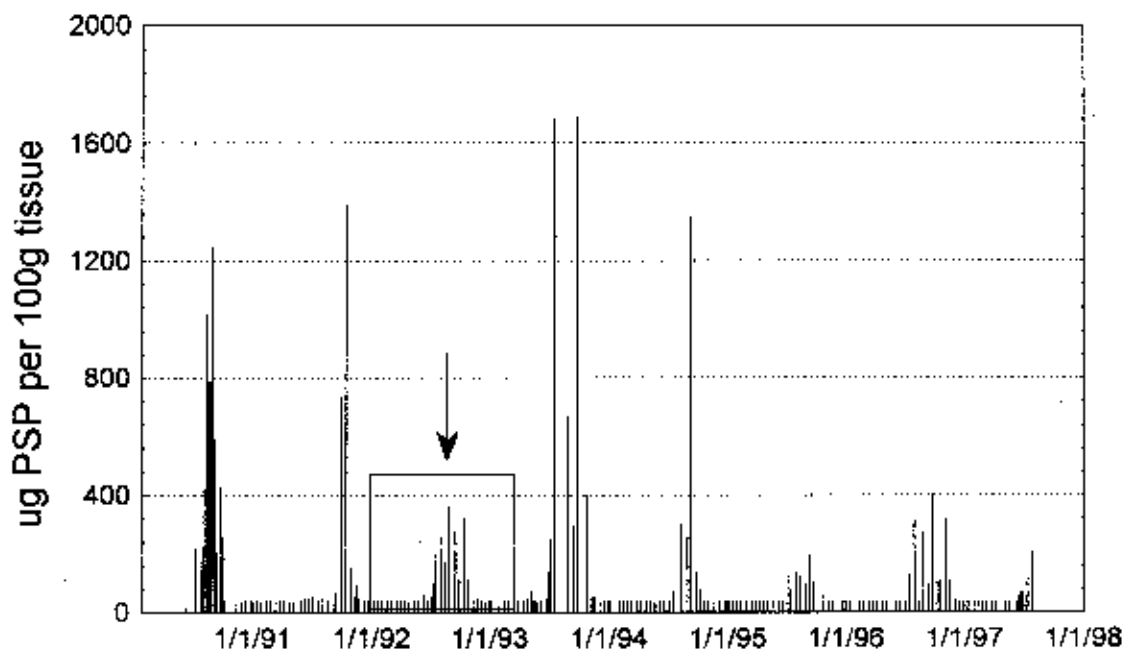


Figure 1. PSP at Sequim Bay (Battelle Labs).

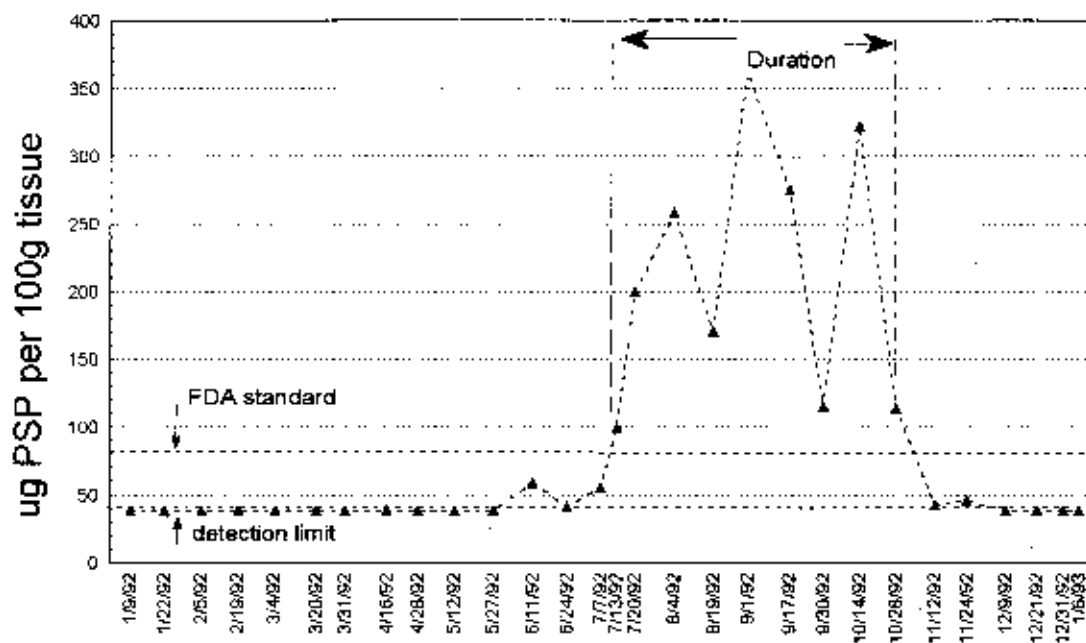


Figure 2. PSP at Sequim Bay (Battelle Labs) 1992.

Two criteria were developed to reduce the highly variable data into a single-value representation for each individual year: 1) “Duration” and, 2) a proposed value termed the “Relative Intensity Index” or RI Index. The concepts are displayed in Figure 2.

The “Duration” is the total number of days in a year when PSP toxin levels in shellfish exceed the FDA standard of 80 micrograms per 100 grams shellfish tissue (see Figure 2).

The RI index is the ratio of the total PSP production (the area under the dotted line connecting PSP levels in Figure 2) to a “standard minimum production” (the area under the dotted line marking the minimum detectable level of PSP, which is 38 micrograms per 100 grams shellfish tissue).

PSP duration provides a clear measure of public health impact (i.e., the period of time when shellfish are unsafe to eat). The PSP RI index considers not only the duration of a bloom, but changes in toxin levels during the bloom. The example in Figure 2 shows PSP duration of 107 days, or nearly a third of the year. The PSP RI index was estimated to be 2.6. Note that if a site shows no PSP during any particular year (i.e., PSP duration is zero), the RI index equals 1. In the future, the RI index may be used to test correlations with environmental factors (i.e., water stratification, nutrients, etc.). Both duration and RI indices were calculated for this technical report. However, the discussion will be restricted to PSP duration only.

Results

PSP criteria were calculated for 24 PSAMP sites. The period of record was 1991 through 1997 for most sites. However, some sites were not sampled until 1992 or 1993. Criteria were calculated only for those years when sampling was done throughout the year.

Figure 3 summarizes PSP impact at the PSAMP sites. PSP duration during the most recent three years (1995 through 1997) was combined into a single “total duration” value. High PSP impact was defined as having a total duration of 100 to 120 days. Moderate PSP impact means total duration of 30 to 60 days. Low PSP impact is total duration of 1 to 15 days. No PSP impact means there were no days when PSP in shellfish exceeded safe levels.

Three sites rated high PSP impact. Two are on the Strait of Juan de Fuca (Sequim Bay State Park and Discovery Bay near Maynard). A third was Quartermaster Harbor in the Main Basin of Puget Sound.

Eight sites showed moderate PSP impact. One is on the Strait (Kilisut Harbor). Three others (Port Orchard, Manchester, and Southworth) are in the Main Basin. The remaining four sites (North Bay, Jarrell Cove, Johnson Point on Nisqually Reach, and Filucy Bay) fell into the moderate group largely due to a very intense bloom in south Puget Sound in late fall 1997. These sites historically have experienced only occasional PSP blooms of low intensity and short duration.

Six stations ranked low in PSP impact. These sites include Port Ludlow and Lofall (in or near upper Hood Canal); Kingston (Main Basin); Steilacoom (south Puget Sound); Drayton Harbor and Birch Bay (both in Strait of Georgia).

The remaining seven sites showed no PSP impact. Five sites are in south Hood Canal, and two (Penn Cove and Holmes Harbor) are in Saratoga Passage.

Figure 4 shows results at four sites on the Strait of Juan de Fuca. PSP duration is consistently prolonged at Battelle Labs, Sequim Bay. In a year-by-year (1993–1996) comparison, PSP duration at Sequim Bay State Park (in the south end of the Bay) was lower than Battelle Labs (near the mouth of the Bay). (Criteria for 1997 were not calculated for Battelle Labs due to closure in July for safety and liability concerns.) This suggests a gradient of effect from the mouth to the head of Sequim Bay.

Discovery Bay (near Maynard) showed slightly less impact than Battelle Labs. Kilisut Harbor (Fort Flagler State Park) was the least affected. All four sites show peak duration in 1993. Sequim Bay State Park shows peak duration in 1993 and 1997. The other sites show peak duration in 1993 only.

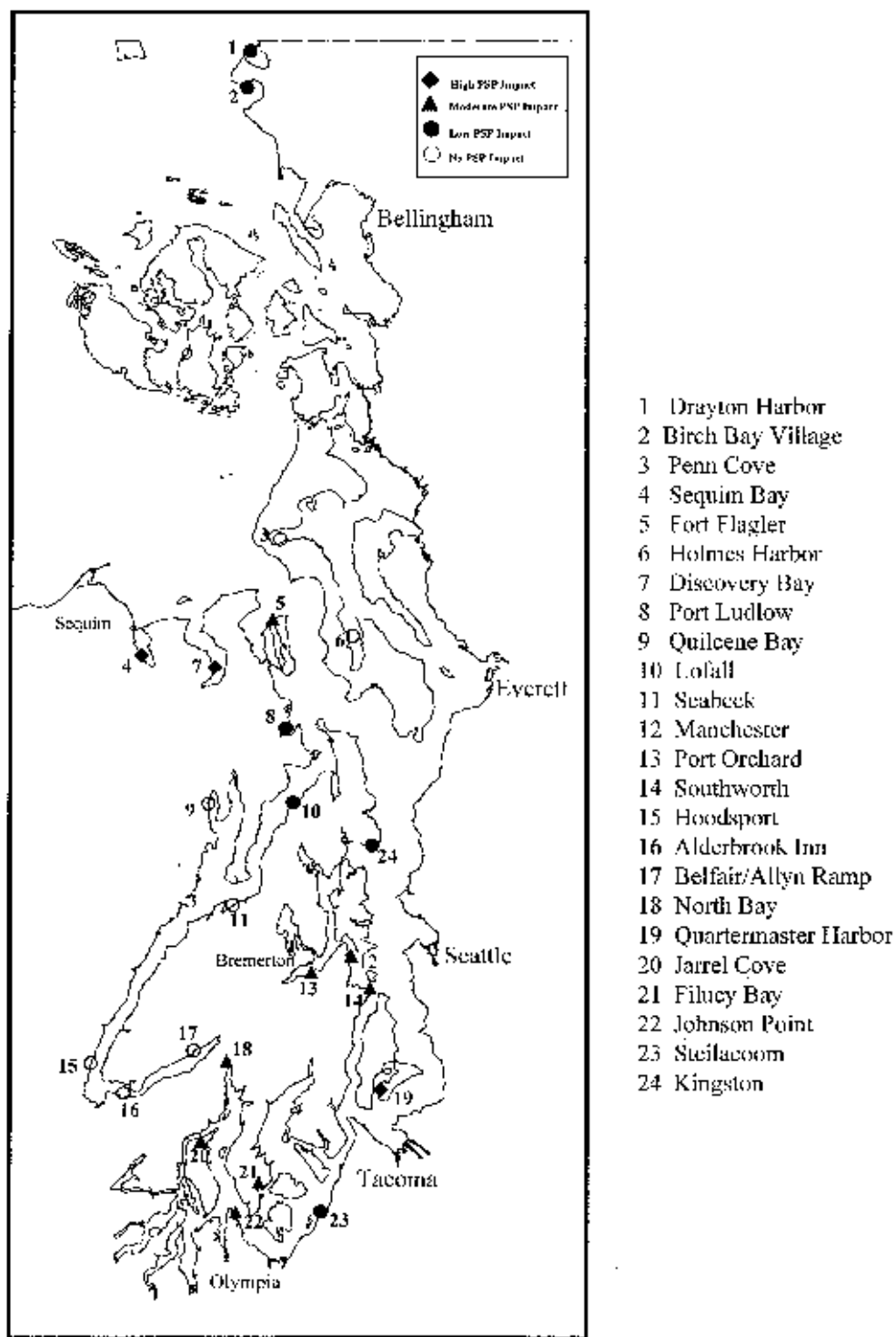


Figure 3. Paralytic shellfish poisoning (PSP) toxin in Puget Sound mussels from January 1995 through December 1997.

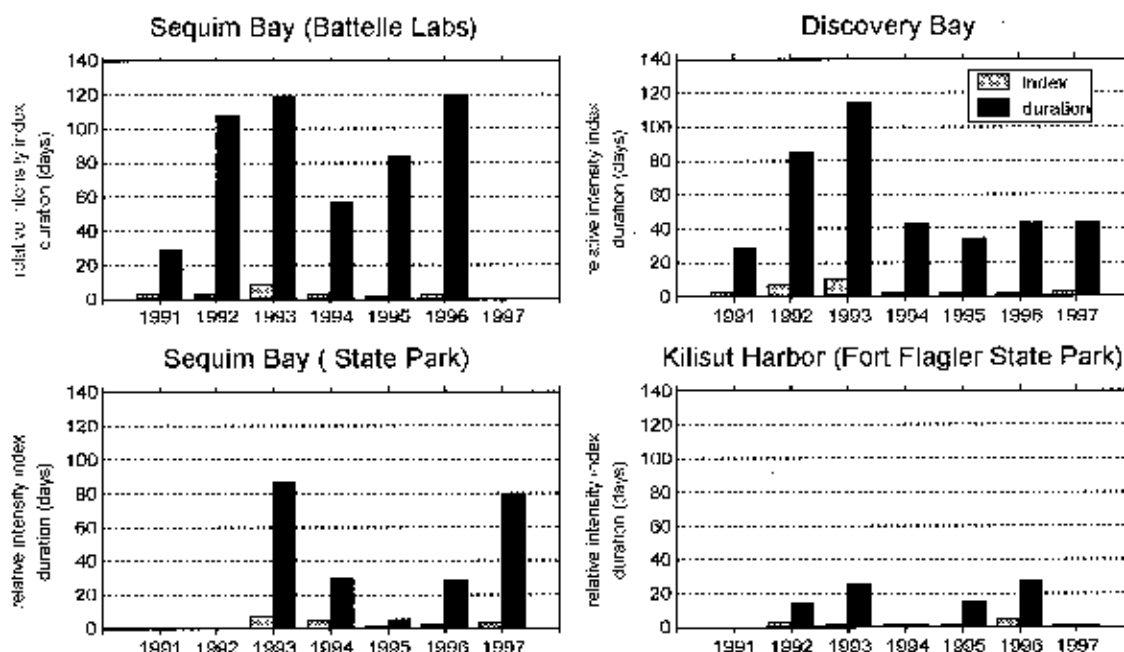


Figure 4. PSP in the Strait of Juan de Fuca.

Figure 5 shows results from three sites in the north end of Puget Sound's Main Basin (including Port Orchard in Sinclair Inlet). Figure 6 shows two sites in the south end of the Main Basin. Durations in Quartermaster Harbor (Dockton County Park, Maury Island) were similar to those of Sequim and Discovery Bay sites. On the other hand, the other Main Basin sites tended to have much less duration. (Note the different scale showing criteria for Quartermaster Harbor graph compared to other Main Basin sites).

Kingston, Manchester, and Southworth showed peak PSP duration in 1993 and 1997. Other years showed no PSP at all (i.e., duration = 0; RI Index = 1). PSP duration in Port Orchard was comparable to most Main Basin sites. However, Port Orchard site differed in timing of peak durations (1995 and 1997). PSP duration in Sinclair Inlet doesn't seem to be overly stimulated by nutrient input from adjacent urban sources (e.g., sewage treatment plants, combined sewer overflows, and stormwater runoff).

Figure 7 shows PSP duration at four sites in south Puget Sound. Peaks occurred in 1994 and 1997. Significant PSP was undetected in other years. In peak years, blooms occurred later than elsewhere in Puget Sound. In fact, the 1997 bloom began in late October and continued through January 1998 (F. Cox 1998, this volume).

Impressions

Spatial Patterns

Maximum PSP duration occurred at Sequim and Discovery Bays on the Strait of Juan de Fuca and at Quartermaster Harbor in the Main Basin of Puget Sound. Saratoga Passage and Hood Canal were free of PSP.

Although Saratoga Passage has had no PSP in recent years, intensive blooms occurred there in the late 1970s. Based on this experience, there is no reason to conclude that the intensive blooms in south Puget Sound this year will become a permanent event. However, lack of complete understanding of phytoplankton dynamics makes reliable predictions impossible. There appears to be no evident relationship between PSP duration and human activity.

Temporal Patterns

A number of sites in the Strait of Juan de Fuca and the Main Basin of Puget Sound show peak PSP duration in 1993 and 1997. South Puget sites show peak duration in 1994 and 1997. This pattern suggests PSP bloom activity in Puget Sound may be cyclic. Continued PSP monitoring coupled with study of interaction with other environmental data is needed to confirm this hypothesis.

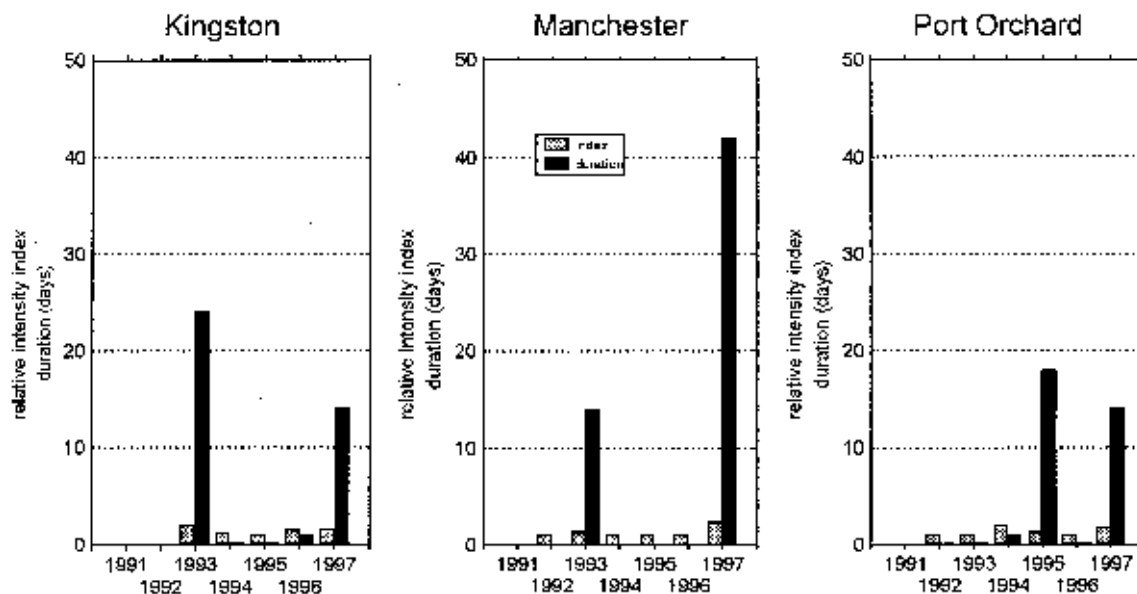


Figure 5. PSP in Main Basin (north).

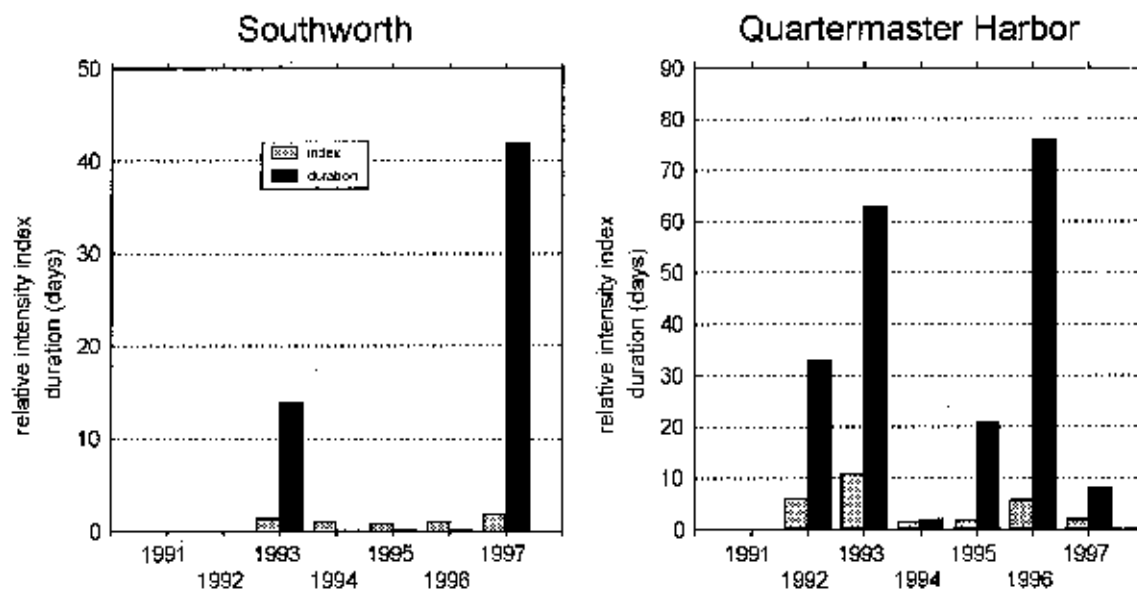


Figure 6. PSP in Main Basin (south).

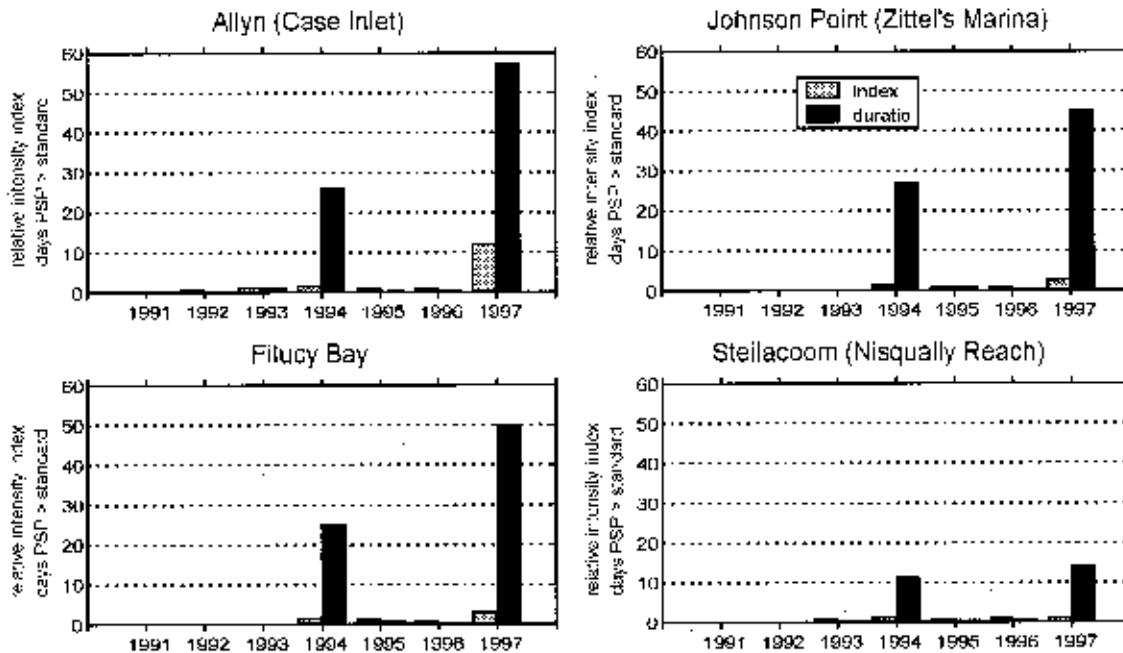


Figure 7. PSP in south Puget Sound.

References

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